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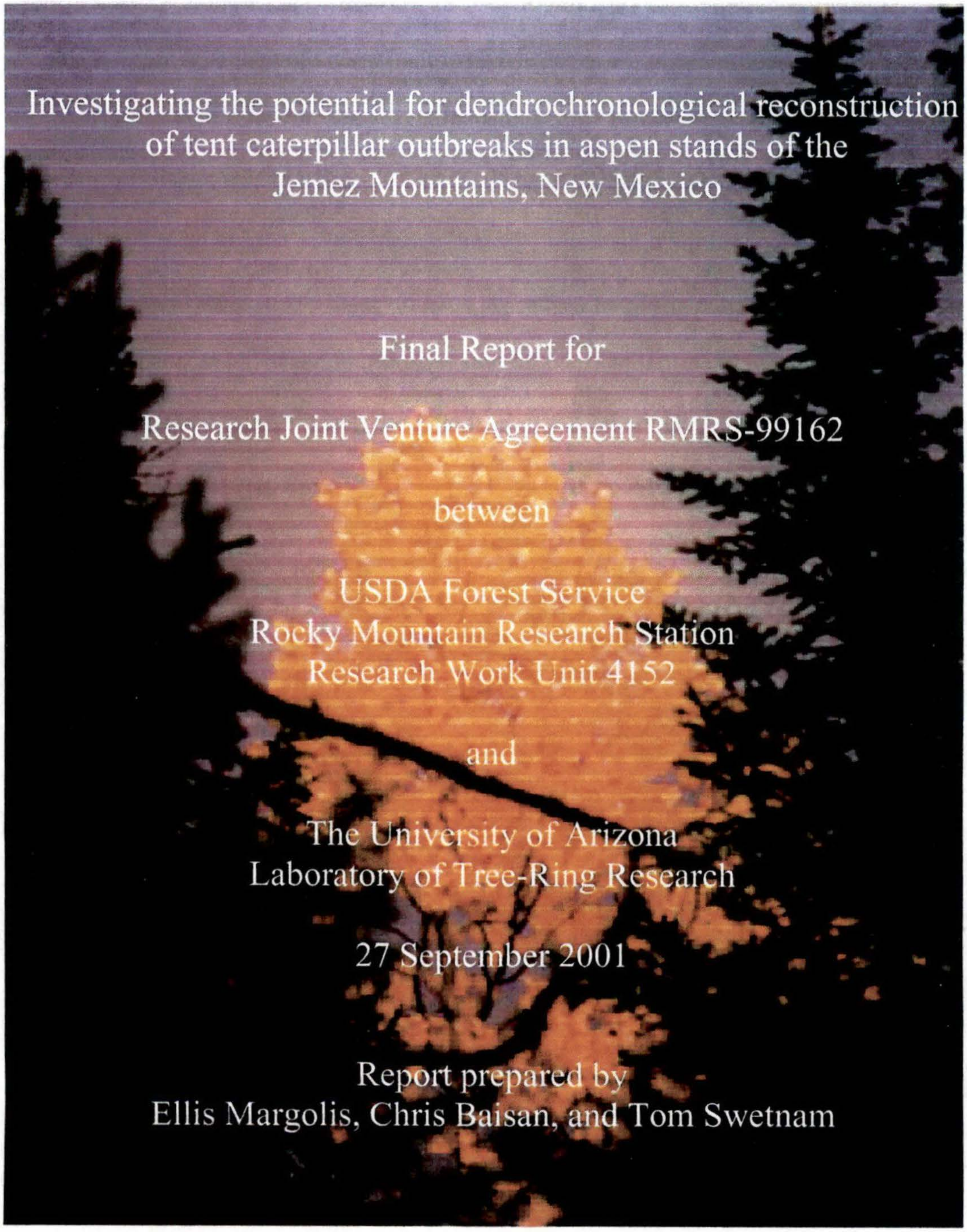
INVESTIGATING THE POTENTIAL FOR DENDROCHRONOLOGICAL RECONSTRUCTION OF TENT CATERPILLAR OUTBREAKS IN ASPEN STANDS OF THE JEMEZ MOUNTAINS, NEW MEXICO



Investigating the potential for dendrochronological reconstruction of tent caterpillar outbreaks in aspen stands of the Jemez Mountains, New Mexico

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Abstract

Dendroecological techniques were used to investigate the potential reconstruction of tent caterpillar outbreaks in the aspen stands of the Jemez Mountains, NM. Multiple, synchronous growth suppressions were evident at all seven study sites between 1886-1999. The Baca Ranch chronology extends back to 1743 and contains multi-year growth suppressions throughout the time series. Several methods were used in an attempt to determine the climate sensitivity of aspen, yet none revealed a consistent climatic response. Lack of an identifiable aspen-climate response prevents the reconstruction of tent caterpillar outbreaks via the host, non-host method. The potential remains for a 250-year tent caterpillar outbreak reconstruction by applying other dendroecological methods.

Introduction

Quaking aspen (*Populus tremuloides* Michx.) is the most widely distributed native tree in North America. In the southwest United States aspen is often the only deciduous tree on upland sites and plays a vital role as wildlife habitat and in maintaining watershed stability (Mitton and Grant 1996). Alteration of the natural disturbance regime, primarily due to fire suppression and grazing, has increased the percentage of stands existing in the mature to over-mature age class to 78%. There is increasing concern regarding the health of these mature aspen communities, which are more susceptible to disease and insect attack (Debyle 1990).

Western tent caterpillar (*Malacosoma californicum* Pack) is one such insect that primarily defoliates quaking aspen in the western U.S. (Jones et al. 1985). The

subspecies *M. californicum fragile* (Stretch) is endemic to the southwest and is the only subspecies reported to cause economic damage due to large defoliation events resulting in stem mortality (Furniss and Carolin 1977). In addition to the direct effects on the aspen forests the epidemic caterpillar populations may have undesirable effects upon water resources and recreation. In a 1950 letter to the Chief of the Forest Service, Regional Forester Otto Lindh reports of caterpillars "piled up in masses three to four feet deep" in and along stream channels in the vicinity of Taos, NM. Due to these conditions water was unsuitable for use by local residents in ten communities, summer residents left their homes and use of the forest came to a halt (Wilford 1951). During a separate outbreak on the Santa Fe National Forest, large numbers of migrating larvae caused highways to be slippery and caused Cumbres & Toltec railroad trains to slip on steep inclines (Schmid and Mata 1996). A better understanding of the population cycles of this insect would help to manage for these outbreak events, with the potential for prediction of future events.

All tent caterpillars have similar lifecycles with adult moths active at night in midsummer. The moths have a wingspan of 25 to 35mm and coloration varies from brown to yellow to gray. These adults lay flat egg masses on branches or the bole of the tree. In approximately two to three weeks the caterpillars are fully formed within the eggs where they overwinter. The first instars hatch in the spring, usually coinciding with the emergence of the new foliage. The larvae spin conspicuous tents where they often congregate in large masses when they are not feeding on the foliage. Mature larvae are blue and black measuring approximately 50mm in length. The larvae have a tendency to

migrate in masses that can lead to the problems previously cited. Silk cocoons are spun in folded leaves or in the duff where an approximate two-week pupation occurs (Furniss and Carolin 1977).

Epidemic tent caterpillar population levels that persist for multiple years can dramatically affect an aspen stand. Defoliation of tens of thousands of acres (Jones et al. 1985) to 100,000 acres of aspen can occur regionally (Graves 1951). Multi-year outbreaks can result in stem mortality, top kill, and severe reduction of annual growth increment (Schmid and Mata 1996). This effect on annual tree growth is reflected in tree ring-widths and using dendrochronological techniques there is potential for prior outbreaks to be reconstructed. Prior studies have used dendrochonologic methods to reconstruct insect outbreaks of various species over centennial time scales. (Swetnam et al. 1985, Veblen et al. 1991, Swetnam and Lynch 1993, Weber and Schweingruber 1995, Speer et al. 2001). No attempts, however, have been made to reconstruct tent caterpillar outbreak events in the southwestern U.S.

The aspen stands present in the Jemez Mountains of northern New Mexico provide an opportunity to study past tent caterpillar outbreaks. The area contains many large aspen stands with some historical documentation of past outbreak events and the presence of individual stems living in excess of 250 years. The purpose of this pilot project was to determine the potential for reconstructing western tent caterpillar epizootic events using dendrochronologic techniques and, if possible, reconstructing the outbreak history in the Jemez Mountains, New Mexico.

Methods

Tree-ring cores from seven aspen sites in the Jemez Mountains of New Mexico were used in the study (Figure 1). The majority of the data used in this study was collected in 1993 as part of a fire history reconstruction in the Jemez Mountains that incorporated aspen age structure data (Touchan et al. 1996). Increment cores from five sites were used in the current study as well as increment cores from two additional locations collected March, 2000. This supplemental collection included conifer samples that were adjacent to the aspen stems sampled.

All cores collected in March 2000 were mounted, surfaced, and cross-dated using standard dendrochronological techniques (Stokes and Smiley 1968). Cores used from the prior study were re-surfaced and independently re-dated. Some individual cores were excluded from further analysis due to severe growth suppressions that prevented accurate cross-dating of the wood. After dating, ring widths were measured with 0.01mm precision and then run through the COFECHA program (Holmes 1983) to identify potential cross-dating and measurement errors. All ring-width measurements were standardized using a 100-year cubic spline in the program ARSTAN (Cook and Holmes 1986). This detrending method preserves greater than 99% of the variance at wavelengths less than 30 years. No reported tent caterpillar outbreak lasted more than ten years; therefore the variation in ring-widths that may identify insect outbreaks was preserved in the resultant chronologies.

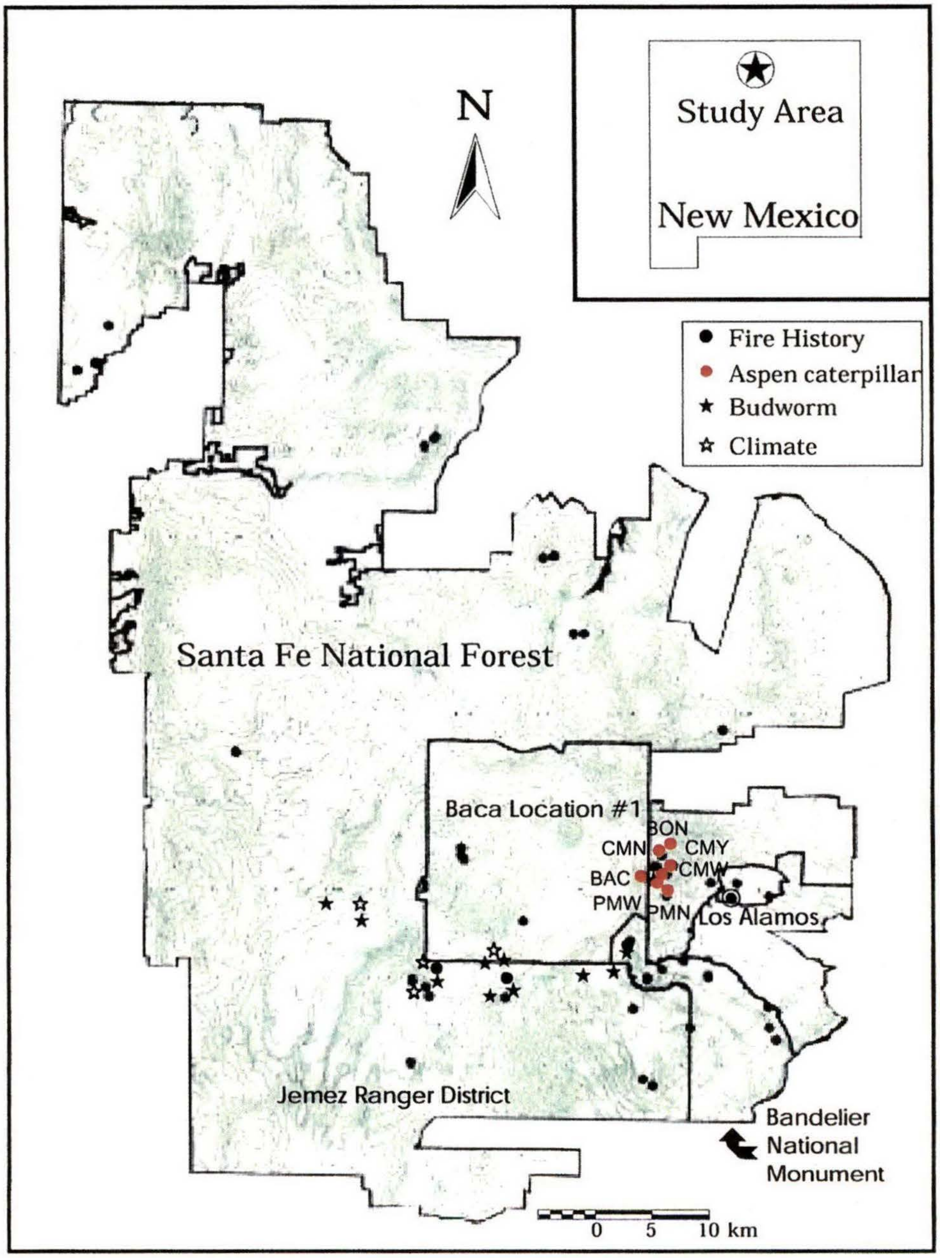


Figure 1. Map of the Jemez Mountains, NM, showing locations of aspen stands sampled for this study.

With the future goal of using a computer program that can identify insect outbreaks (i.e. OUTBREAK) in corrected tree-ring indices (Swetnam et al. 1995), the climate response of aspen was investigated by several methods. First, a climate response function program RESPO was used to examine the climate response of the aspen chronologies. A nine-year running correlation analysis between ring-width and both precipitation and temperature was also performed. Temperature and precipitation data (1910-1993) from Jemez Springs, NM were used as the climate data input for the response function analysis and the correlation analysis. At sites where adjacent conifers were collected, the aspen/conifer pairs were examined. Comparisons of the aspen chronologies with previously collect pine and spruce chronologies, as well as a precipitation reconstruction, were also conducted to further examine the climate response of aspen.

Historical documentation of insect outbreaks was researched in an attempt to confirm location and temporal extent of known outbreaks near the study area. This consisted of searching through Forest Service insect and disease reports, and insect control reports, for the National Forests in the Southwestern Region. Local researchers also proved to be valuable resources.

Results

Cores from 17-31 aspen stems per stand, at seven sites were measured (Table 1). The data cover the period 1743-1999, with a common interval for all sites from 1886-1992. Additional cores are available for some sites, but the lack of variation within sites

(interseries intercorrelation: .685 - .725) suggests that the current sample size adequately represents the variation within the sites.

Site Name(Site Code)	Radii	trees	years
Canada Bonita (BON)	30	17	1877-1992
Pajarito Mtn. North(PMN)	37	20	1886-1992
Camp May West (CMW)	57	31	1863-1992
Pajarito Mtn. West (PMW)	37	20	1851-1992
Camp May North (CMN)	35	20	1863-1992
Camp May (CMY)	24	19	1793-1999
Baca Ranch (BAC)	29	19	1743-1999
Totals	**249**	**146**	**1743-1999**

Table 1. Summary of measured aspen samples from the Jemez Mountains, NM

Investigating the climate response of aspen

All attempts to determine the climate response of the aspen samples were inconclusive. The response function analysis revealed no consistently strong monthly precipitation or temperature signals. The correlation coefficient exercise demonstrates a similarly inconsistent growth response to a single variable throughout the timeseries (Figure 2). The attempted comparison of the aspen time series to other species resulted in no consistently similar growth responses through time (Figure 3). The comparison of aspen growth with other species included the paired aspen/ Douglas-fir samples collected at CMY and BAC (Figure 4). These did not produce any consistent similarities in growth response. In summary, the climate response of aspen was not able to be determined through the various methods. Therefore, no control (non host) chronology could be used to remove the climatic effect from the host chronologies.

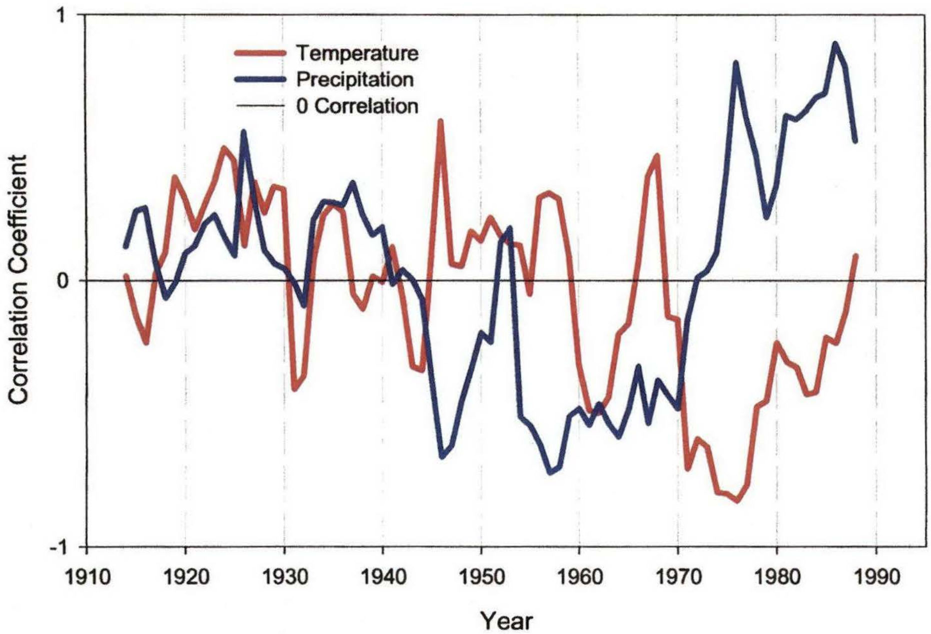


Figure 2. CMN aspen chronology vs Jemez Springs, NM temperature and precipitation: 9-year running correlation coefficients.

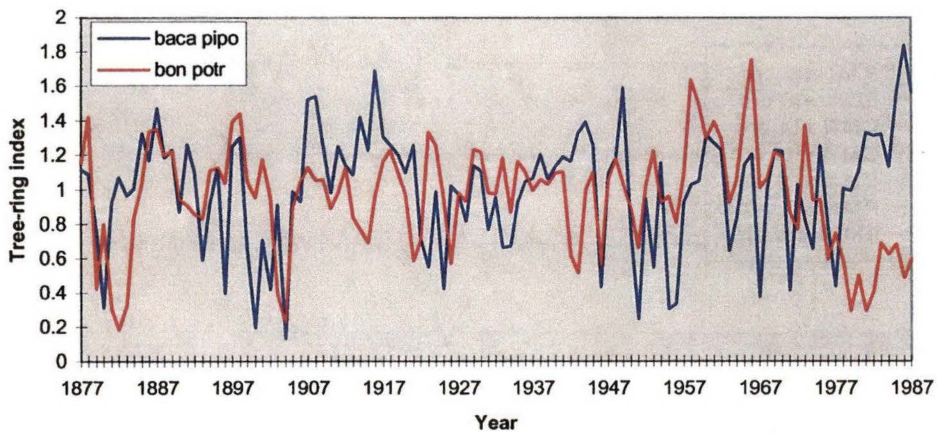


Figure 3. Baca ranch ponderosa pine standard chronology plotted against BON aspen chronology.

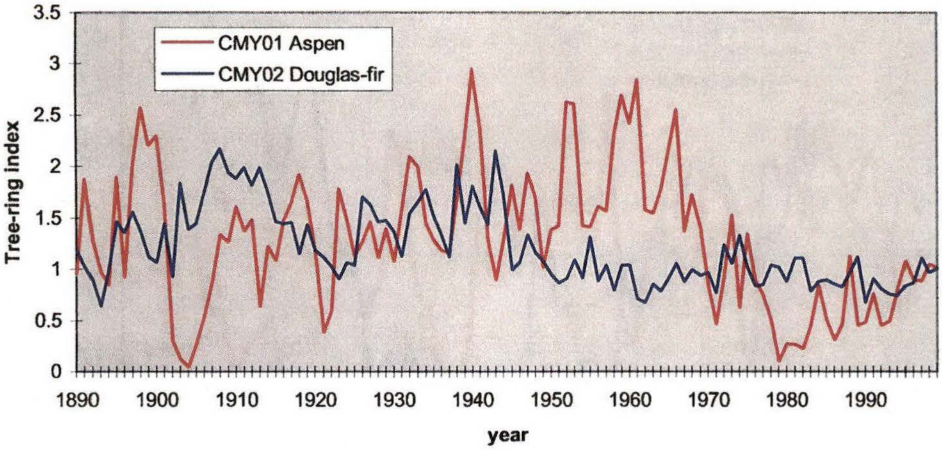


Figure 4. Aspen tree-ring index compared with adjacent Douglas-fir tree-ring index

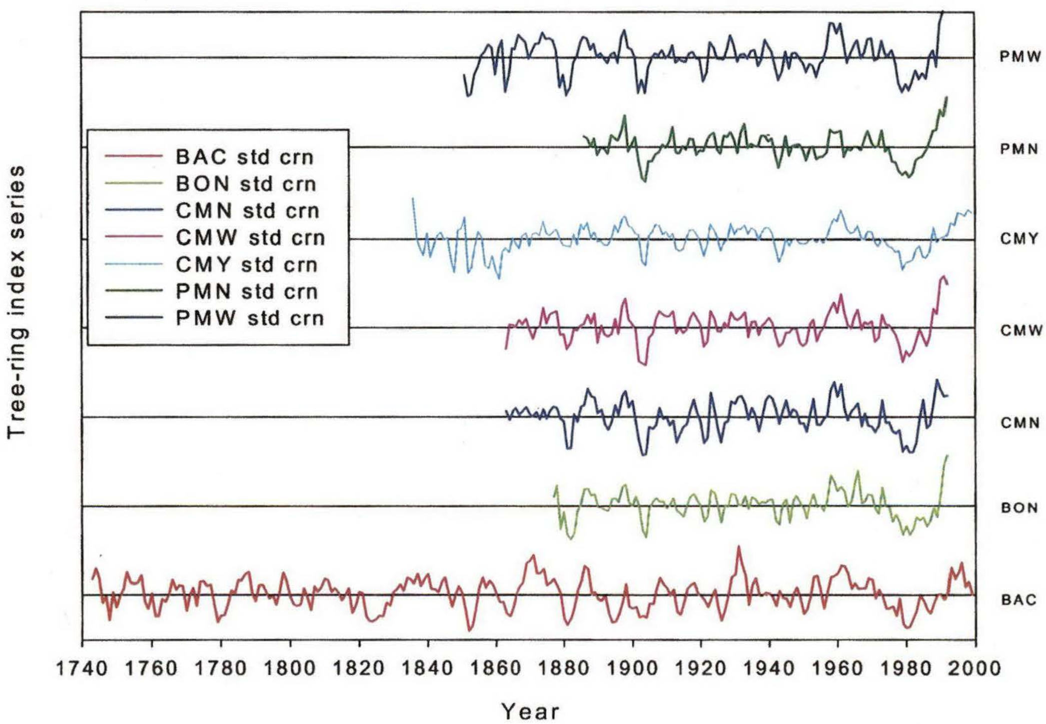


Figure 5. Standard tree-ring index chronologies of the seven aspen study sites.

Graphical trends

The seven standardized chronologies fit with a 100-year spline are shown in Figure 5. A synchronous growth suppression is graphically evident at all sites circa 1980. Synchronous growth suppressions at all sites are also noted between 1940-1960 and circa 1900. All six sites extending prior to 1880 show a synchronous suppression circa 1880. Three sites, BAC, CMY, and PMW extend back to 1850 and all the chronologies show a growth suppression circa 1850. The BAC chronology, which extends back to 1743, shows evidence of episodic suppression events over the past 250 years.

Trends in the wood

Between 1976 and 1989 there were suppression observed in the wood at all sites, with missing rings present at multiple sites during this period (Figure 6). Annual rings with little or no latewood, "light rings," were commonly observed during suppressions throughout the cores at all sites. Particularly evident were the signature light rings in the early 1900's (Figure 6). In the BAC chronology, missing rings and narrow light rings were present as far back as 1780. Between 1940 and 1960 multiple growth suppressions are evident in the cores, particularly at CMY. This evidence may be related to dead leaders and stem crooks observed in the field (Figure 7).

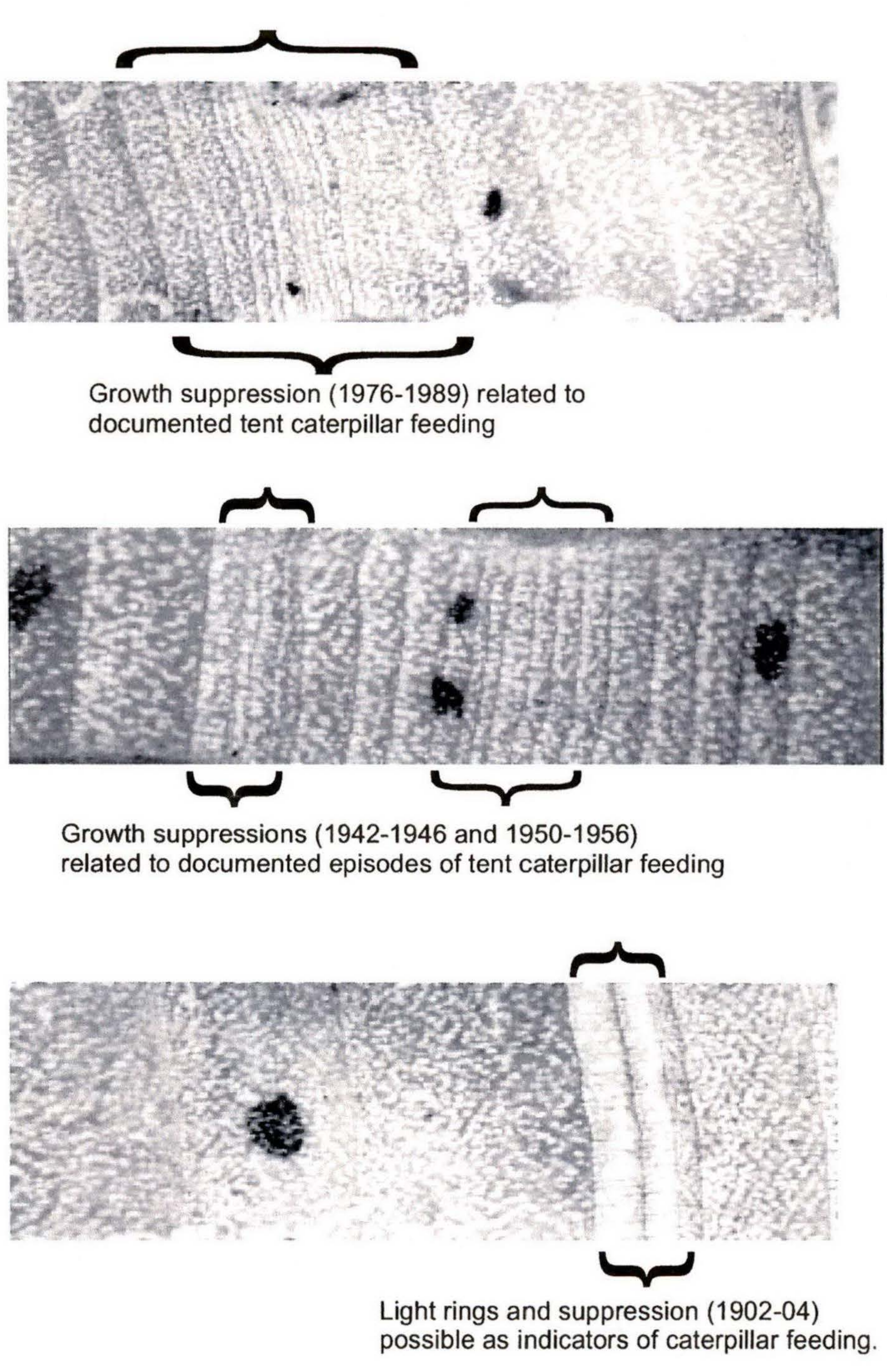
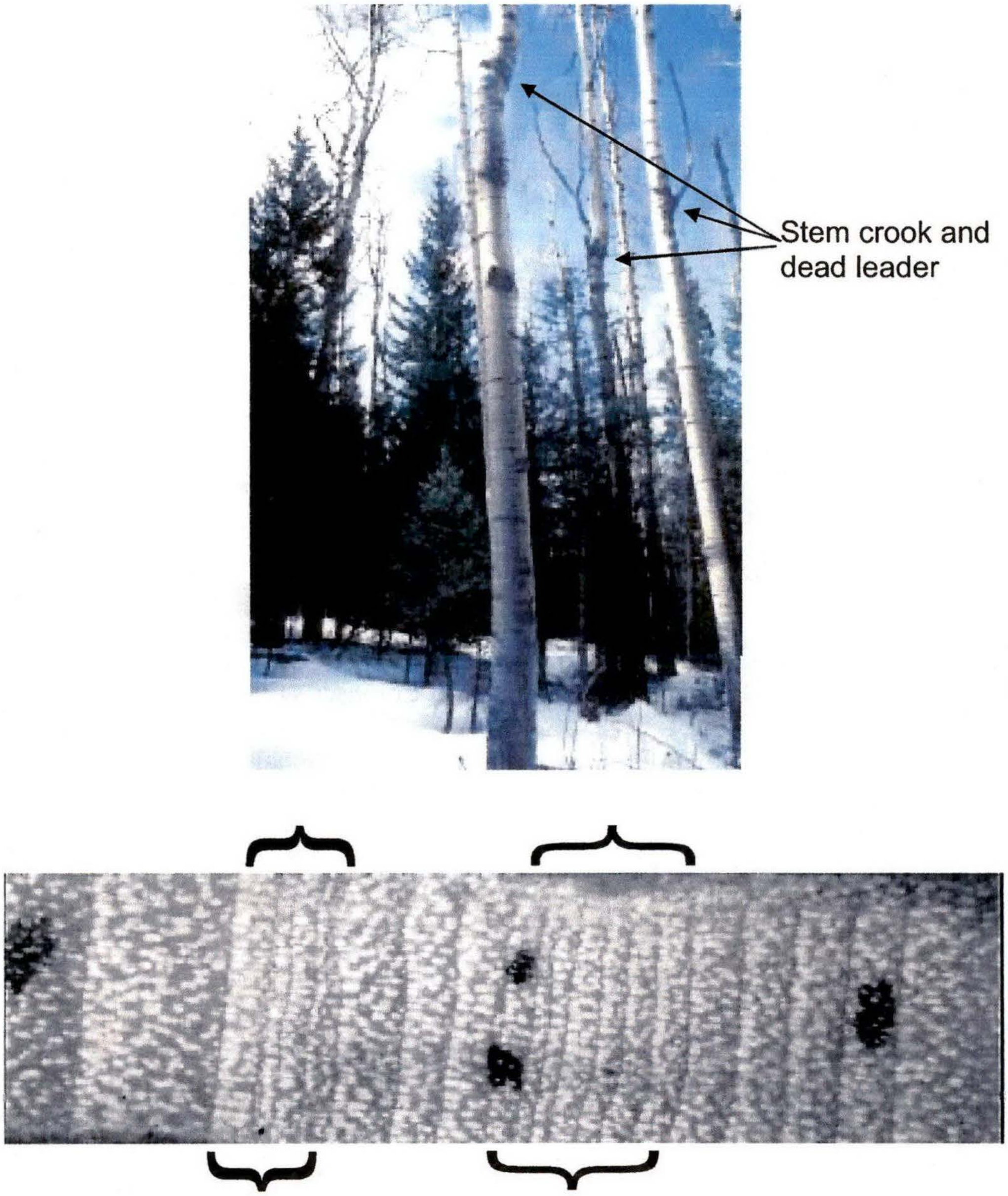


Figure 6. Image of growth suppression during documented outbreak (1976-1982) and other growth suppression signatures observed in the ring widths.



Growth suppressions (1942-1946 and 1950-1956) possibly associated with apical death and crooked growth form in this aspen stand at Camp May.

Figure 7. CMY (1942-1946, 1950-1956) growth suppression images with dead leaders and crooked trunks of corresponding aspen stems.

Historical Documents

Forest Service insect outbreak reports indicate at least six years of continuous tent caterpillar defoliation in the Jemez Mountains beginning in 1976 (USDA 1977-1982). No records were available after 1982. The reports particularly note defoliation as "noticeably severe" in the vicinity of Los Alamos and Bandelier National Monument. Particular reference was made to Camp May as well as Baca Ranch, where reports described 29,000 acres of defoliated aspen (USDA 1982). These reports are in agreement with personal observations of Craig Allen (USGS-BRD Jemez Mountain Field Station) regarding a tent caterpillar outbreak circa 1980. Other historical insect outbreak reports (circa 1950) from the Forest Insect Laboratory at Fort Collins, CO suggest widespread tent caterpillar defoliation on both the Carson and Santa Fe National Forests in northern New Mexico. A September 1, 1950 report by Noel D. Wygant (Entomologist in Charge) mentions severe defoliation in 1950, with expectations of continued outbreak the following year.

Discussion

The similarities observed in the wood at all sites to a documented insect outbreak (1976-1982), suggests that the trees are responding in a similar manner to repeated tent caterpillar defoliation. Synchronous signature rings were observed in other growth suppressions circa 1900, 1880, and 1850, yet one cannot unequivocally attribute the cause of these events to caterpillar herbivory. These are known drought periods in the Rio Grande Basin, thus the decreased ring-width increments may be caused in part by a

climate response. However, no clear climate response was identified amongst the aspen chronologies; therefore a drought response is not necessarily supported as a cause of the growth suppressions. This result prevents the utilization of the established host, non-host outbreak determination method, since climate response of the host species is required.

In addition to the possibility of climate caused growth suppression, there are other confounding factors related to aspen ecology. Several insect species including large aspen tortrix, *Choristoneura conflictana* (Walker) and a leaf roller, *Anacampsis niveopulvella* (Chambers) have defoliated large expanses of aspen forests in the southwest (Furniss and Carolin 1977, Jones et al. 1985, personal observation 1999). Ink spot disease can also defoliate large expanses of aspen (USDA 1972). Confounding biotic causes of decreased growth and alteration of annual ring morphology in aspen must be ruled out if a tent caterpillar outbreak reconstruction is to be successful.

Human intervention into the periodic tent caterpillar outbreaks may help explain some of the growth suppressions observed. The historical insect control reports from New Mexico revealed the initiation of biological control tests for tent caterpillar outbreaks in the 1940's. Ground application of insecticide was also initiated in the 1940's in response to the tent caterpillar outbreaks on the Carson and Santa Fe National Forests. This escalated to aerial insecticide application beginning in 1950, due to the severity of the outbreaks (USDA 1942-1947, USDA 1949-1955). This anthropogenic control of the insect outbreaks of the 1940's and the 1950's may explain the weak suppression signal present in the time series (figure 5). The amplitude of the

suppressions circa 1980, 1900, 1880, 1850, 1820, and 1780 is greater than the suppressions circa 1940 and 1950. The possibility of anthropogenic effects on the intensity of the caterpillar outbreaks must be considered if a caterpillar growth reduction "signal" is sought from known events.

Future research possibilities include locating aspen stands in the southwest without defoliation events during recent decades. These stands may have a more consistent and easily identifiable climate signal than the stands in the Jemez Mountains. This may be accomplished by investigation through local sources and further examination of the forest service insect outbreak reports. Examination of the insect outbreak reports may also provide evidence for other documented tent caterpillar outbreaks that coincide with the identified growth suppressions. Multiple confirmed outbreaks at a site that match growth changes in the increment cores could provide a firm basis for identifying the specific growth response. Additionally, stands with documented history of other defoliators could be used to identify growth effect signatures caused by feeding of these insects. Comparison of the growth response might lead to the ability to separate the cause of growth suppressions based on anatomical features or other growth effects.

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